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VOLUME 81 PAPER No. 800

PROCEEDINGS

AMERICAN SOCIETY
OF
CIVIL ENGINEERS

SEPTEMBER, 1955

MISSOURI RIVER BASIN PLAN IN OPERATION

by Wendell E. Johnson, M. ASCE

WATERWAYS DIVISION

{Discussion open until January 1, 1956}

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Printed in the United States of America

Headquarters of the Society
33 W. 39th St.
New York 18, N. Y.

PRICE $0.50 PER COPY

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This paper was published at 1745 S. State Street, Ann Arbor, Mich., by the American Society of Civil Engineers. Editorial and General Offices are at 33 West Thirty-ninth Street, New York 18, N. Y.

MISSOURI RIVER BASIN PLAN IN OPERATION[1]

Wendell E. Johnson,[2] M. ASCE

INTRODUCTION

The much discussed Missouri Basin development is beginning to pay dividends. During the nine years it has been under construction, the Basin plan and the organizations which are carrying it out have been the subject of considerable comment and debate by engineers, politicians, educators, laymen, and even by some who have yet to set foot in the 530,000 square mile area which comprises one-sixth of the United States.

With all of this talk there has also been plenty of action. The Corps of Engineers and the Bureau of Reclamation, who are doing most of the construction, have been completing dams, levees, and channel works to harness the waters of the Missouri and put them to work. During the past several years, the progress which these agencies and others are making is beginning to be expressed in concrete terms of flood prevention, irrigated acres, power revenues, and river traffic, instead of in terms of percentages of completion.

Basin Description

The Missouri Basin is an area of 530,000 square miles—one-sixth of the United States. The river begins in the Rocky Mountains in Montana; runs through the semi-arid plains of the Dakotas, Nebraska, and Kansas; and empties into the Mississippi River near St. Louis. Precipitation varies from less than 10 inches per year in the western plains to over 45 inches per year in the eastern areas. The economy is predominantly agricultural and, except for a few localities, industrial areas are largely confined to the eastern and southern portions. In the northern and western areas drouth is the principal water resource problem, while in the southern and eastern portions flood problems are of more concern. The 11 year drouth of the 1930's was followed by a series of wet years and disastrous floods. Climaxing this wet period was the record breaking 1951 flood in the lower basin, which resulted from torrential rains in Kansas, and the 1952 flood in the upper and middle basins, which resulted from the rapid thaw of an abnormally high snow cover over ice-covered ground. This record of alternate periods of flood and drouth and the havoc they wrought provided the impetus for a comprehensive water development program to provide greater stability to the Basin economy.

Description of Plan

The plan for water resource development being carried out by the Corps of Engineers and the Bureau of Reclamation, which was developed in 1943 and

1. Address before the Waterways Division American Society of Civil Engineers, St. Louis, Missouri, June 14, 1955.
2. Chief, Eng. Div., Corps of Engrs., Missouri River Div., Omaha, Nebr.

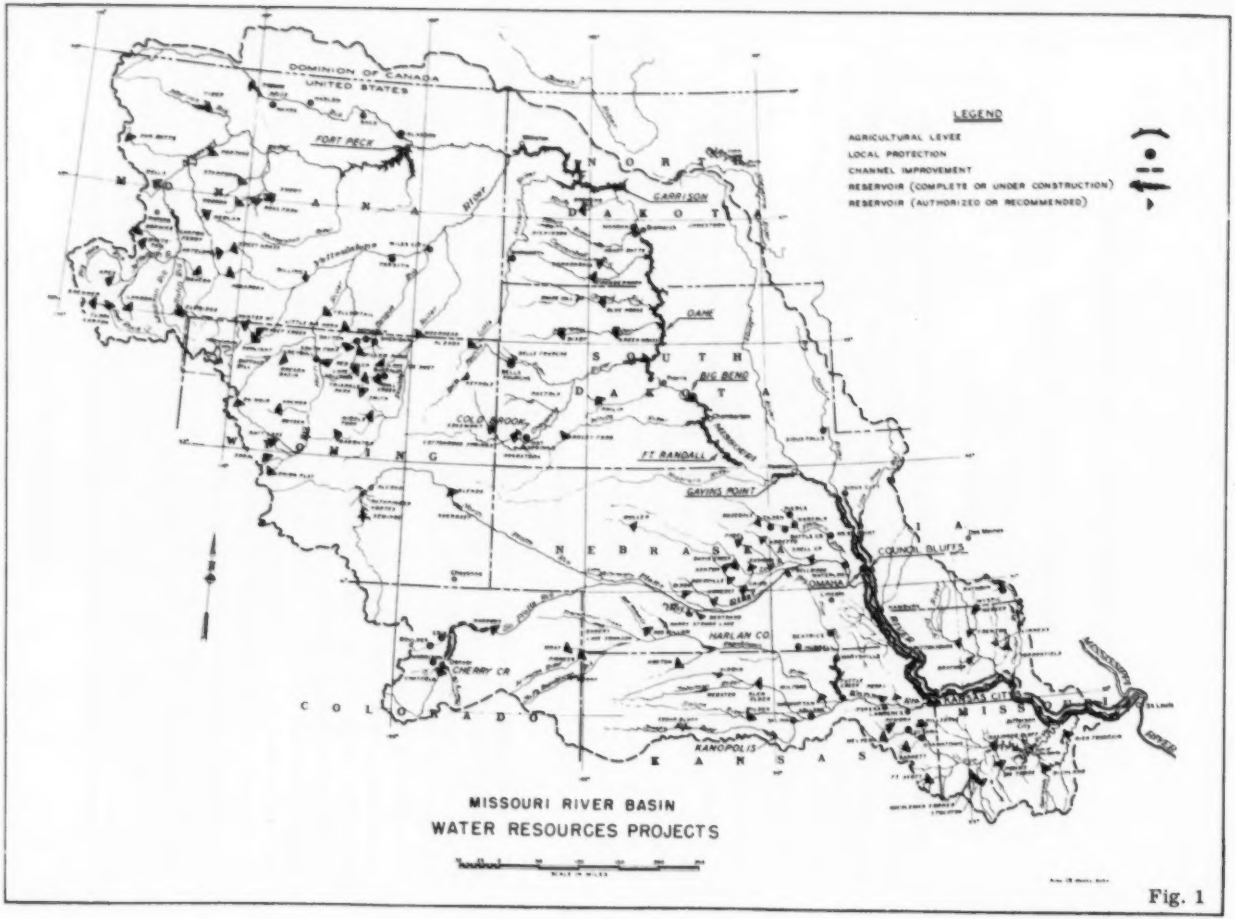

LEGEND
AGRICULTURAL LEVEE
LOCAL PROTECTION
CHANNEL IMPROVEMENT
RESERVOIR (COMPLETE OR UNDER CONSTRUCTION)
RESERVOIR (AUTHORIZED OR RECOMMENDED)
DOMINION OF CANADA
UNITED STATES
FORT PECK
GARRISON
OAHE
BIG BEND
FT RANDALL
GAVINS POINT
COLD BROOK
CHERRY CR
HARLAN CO
COUNCIL BLUFFS
OMAHA
KANSAS CITY
KANOPOLIS
MONTANA
NORTH DAKOTA
SOUTH DAKOTA
WYOMING
NEBRASKA
COLORADO
KANSAS
MISSOURI RIVER BASIN
WATER RESOURCES PROJECTS

Fig. 1

1944, provides for the storage of flood waters in multiple purpose reservoirs to reduce flood damages, and their subsequent release on a regulated basis to benefit irrigation, navigation, water supply, and pollution abatement, and to develop hydro-electric power.

Main Stem Reservoir System

The main portions of the Basin plan are shown on Fig. 1. The backbone of the development is the main stem reservoir system in Montana and the Dakotas. Principal statistics regarding these reservoir projects are shown in Table 1 below.

Project	Storage Capacity in Acre Feet	Head in Ft.	Power Plant	Status
Fort Peck	19,400,000	213	165,000	In Operation
Garrison	23,000,000	174	400,000	In Partial Operation
Oahe	23,600,000	208	425,000*	Under Construction
Big Bend	340,000*	60*	120,000*	Authorized
Fort Randall	6,300,000	138	320,000	In Operation
Gavins Point	540,000	51	100,000	Under Construction

*Tentative

The Fort Peck reservoir began to store water in 1938 and generate power in 1943. The Fort Randall reservoir began to store water in 1952 and power generation was begun in 1953. Garrison storage started in 1953 and power generation will begin this fall (1955).

The main stem dams are all earth embankment with chute spillways in the abutments. At all of the projects, except Big Bend and Gavins Point, tunnels are utilized for power releases and for general regulation. The embankments of three of the dams are the world's largest earth fills, Fort Peck containing over 100 million cubic yards placed hydraulically, and Garrison and Oahe each containing about 75 million cubic yards of rolled fill. The size of the projects has provided the incentive for the development of many unique construction techniques. Earth-moving has been accomplished with some of the world's largest equipment, including 11 cubic-yard shovels and 35 cubic-yard trucks. Closure of the embankment at Fort Randall was performed by means of a dredge which pumped chalk having a maximum size up to about 9 inches in diameter. The most recent development involves the use of a continuous mining machine in the excavation of the tunnels in the Pierre shale formation at the Oahe project. Figs. 2, 3, and 4 show construction photographs of the projects. Fig. 5 shows the mining machine outside of one of the Oahe tunnels.

Bank Stabilization and Navigation

Below this main stem reservoir system, the great flood plain of the Missouri River contains nearly two million acres of rich farm land. The width of the flood plain varies from a few miles to a maximum of 17 miles, and in its meanderings, the river has occupied almost every square mile. Under natural conditions, the river erodes an average of 10,000 acres every year. After many years of experimentation and piecemeal attempts at improvement, a comprehensive program of bank stabilization was undertaken in 1929 on the river from Sioux City to the mouth to provide a nine-foot

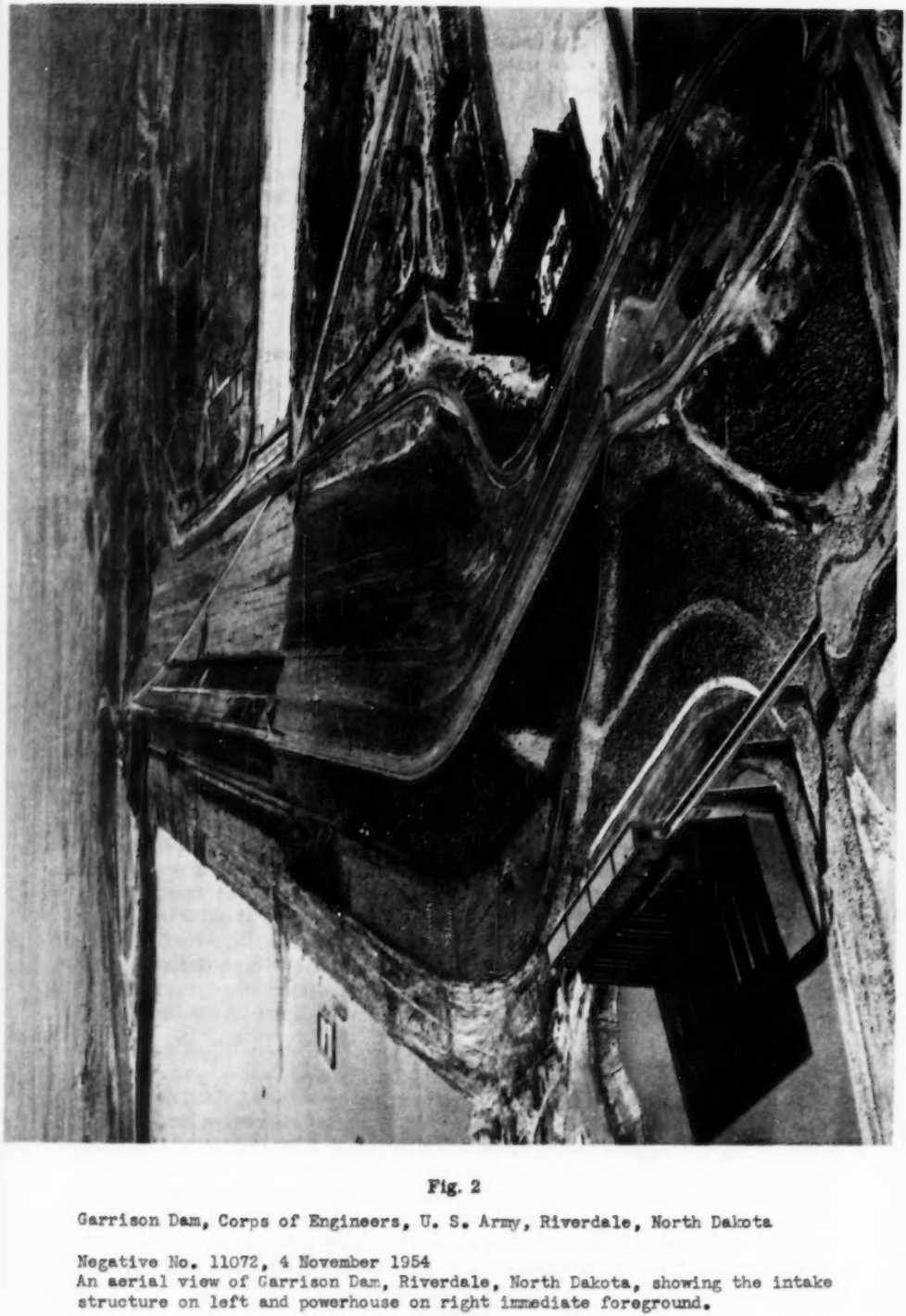


Fig. 2

Garrison Dam, Corps of Engineers, U. S. Army, Riverdale, North Dakota

Negative No. 11072, 4 November 1954
An aerial view of Garrison Dam, Riverdale, North Dakota, showing the intake structure on left and powerhouse on right immediate foreground.

Fig. 3

CORPS OF ENGINEERS, U. S. ARMY
OMAHA DISTRICT
OMAHA, NEBRASKA

Photo No. FRD 1998
October 21, 1954

FORT RANDALL DAM & RESERVOIR

The nearly completed Fort Randall Dam, built by the Corps of Engineers' Omaha District across the Missouri River at Pickstown, South Dakota, is already providing flood control, hydroelectric power and water for navigation and other downstream uses. Standing deep in the reservoir immediately upstream from the earth embankment is the huge 180-foot intake-upstream portal for the twelve tunnels that carry flood control and power releases through the dam. The surge tanks and powerhouse are behind the intake on the downstream side of the embankment. The spillway to the right covers 40 acres with thick reinforced concrete.

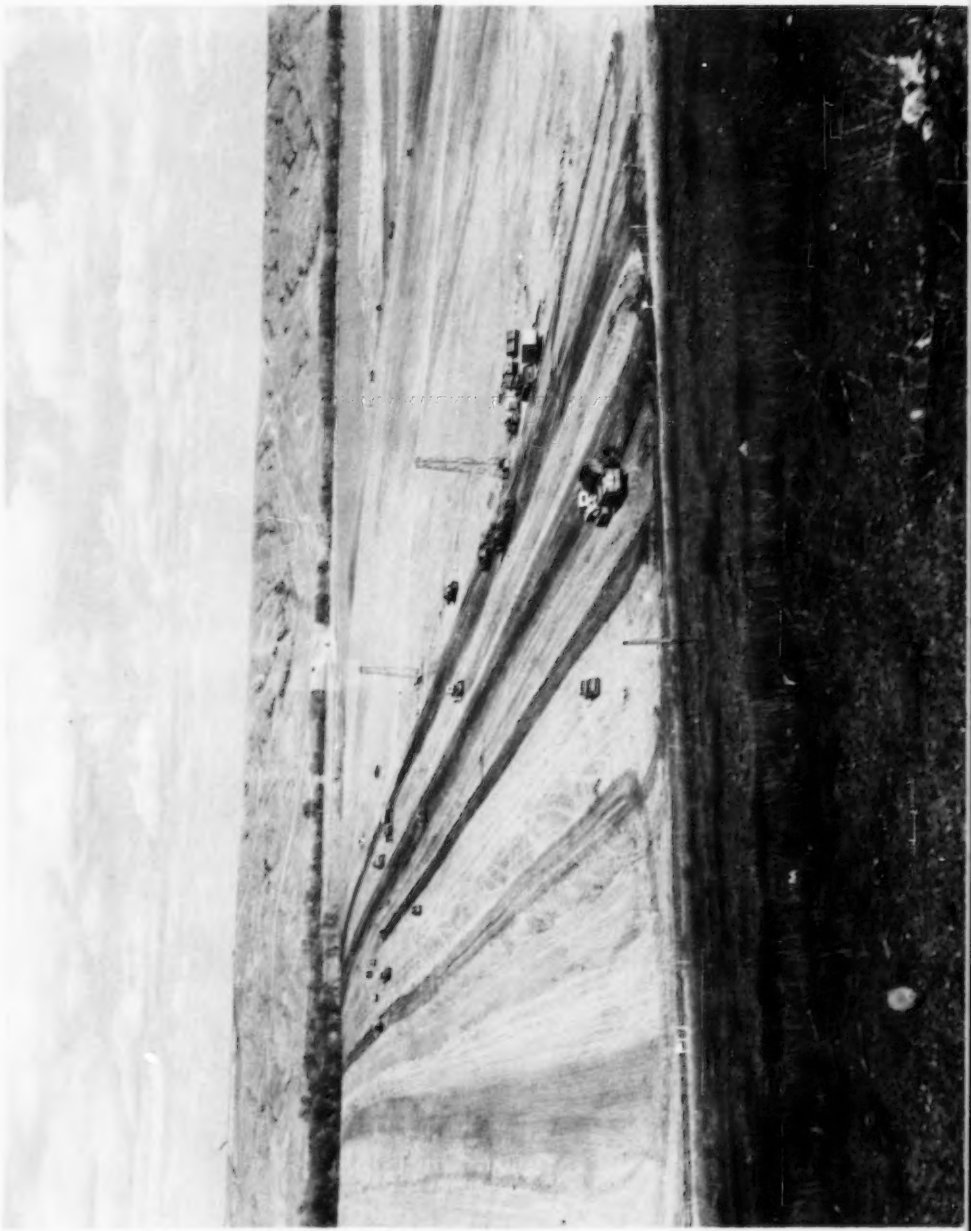


FIG. 4

CORPS OF ENGINEERS, U. S. ARMY
OMAHA DISTRICT
OMAHA, NEBRASKA

Photo No. Oahe-759
May 4, 1955

EARTHWORK, STAGE III, EMBANKMENT, OAHE DAM

General view of activities in center section fill. Right Bank looking from top of Stage I fill.

Fig. 5

Oahe Dam and Reservoir, Pierre, South Dakota, No. 587, 12 October 1954

Outlet Works Stage I
General View, from Contractor's Batch Plant, shows over-all construction progress on Intake Towers 1 through 6. Mining machine is shown in front of Intake Tower #1.

navigation channel and to protect the bottom lands against erosion from the river. This program involves a system of pile dikes and rock revetments which use the energy of the river to develop the channel into a series of continuous, easy bends. By this means, the banks are stabilized permanently, and a nine-foot channel is achieved through contraction. Although this part of the program received a serious setback in World War II, due to a virtual suspension of work, good progress is now being made. Between Omaha and the mouth, the river has largely been captured, and remaining operations are concentrated on improving alinements and completing rock revetments. The present minimum depth from Kansas City to the mouth is 7 feet. Between Kansas City and Omaha, minimum depth is about 6-1/2 feet. Between Omaha and Sioux City, the river is essentially wild, but in 1954 stabilization work was resumed, and present indications are that, from the point of view of construction activities, this reach will be the busiest part of the river during the next few years.

Local Protection Works

In 1947 the work in the lower river was expanded by the initiation of construction of the agricultural levee system. A total of 225 miles of levees protecting 195,500 acres of land has been completed between Omaha and Kansas City. Since the outbreak of hostilities in Korea no new agricultural levees have been begun, but present schedules contemplate a resumption of this phase of the program this year.

Municipal levees have been provided at Omaha, Council Bluffs, and the Kansas Citys on the main stem and at many places on the tributaries. At Omaha, Council Bluffs, and the Kansas Citys the levees are dependent upon upstream storage and are provided primarily to take care of the flows originating in the tributary areas below the reservoirs which are uncontrolled. In the case of the Omaha and Council Bluffs levees, the required upstream storage is either in operation or under construction, but at Kansas Citys, only a small part of the essential storage on the Kansas River has been provided.

Lower Basin

In fact, Kansas City is the point on the Missouri which divides the basin from the point of view of progress on water resource development. Above Kansas City a major portion of the Corps of Engineers' program and a substantial part of the Bureau of Reclamation reservoir program is complete or underway. At and below Kansas City, however, the major tributaries of the Kansas, the Grand, and the Osage enter the Missouri, and on these progress has not been satisfactory.

In the western and more arid portion of the Kansas Basin, fairly good progress has been made. Kanopolis, constructed by the Corps, and Cedar Bluffs, constructed by the Bureau, effectively control the upper Smoky Hill River; Webster and Kirwin Reservoirs, under construction by the Bureau, will control the upper Solomon; and Harlan County Reservoir, supplemented by a number of smaller Bureau reservoirs upstream, controls the upper Republican. In this western portion of the basin, only Wilson Reservoir on the Saline River, Glen Elder on the lower Solomon, Milford Reservoir on the lower Republican, and several smaller reservoirs on the upper tributaries, remain to complete an effective flood control and water conservation storage system. A small start is also being made on planning municipal levees; for example, with the Kanopolis and Cedar Bluffs Reservoirs in operation,

planning may proceed on a levee and channel project at Salina just downstream. A project at Abilene which is independent of reservoir storage is also scheduled to be started soon.

In the eastern portion of the basin, however, the story is decidedly different. Here the authorized plan includes the Tuttle Creek Reservoir on the Blue River, Milford Reservoir on the lower Republican, and Perry Creek Reservoir on the Delaware. Other smaller reservoirs are under study and appear to have promise. However, the residents in this portion of the basin are divided in their views on flood control methods. One group favors continuing with the approved reservoir storage program, and the other advocates relying on the upland watershed and small reservoir program of the Department of Agriculture. I must make it clear that this latter group does not include responsible leaders of the Department of Agriculture who have stated on many occasions that their program is designed primarily for protection of the uplands and will have but minor effect on major floods. With this divergence in views, however, little or no progress is being made on the reservoir storage system, the municipal protection in the lower Kansas Basin, or the agricultural levees below Kansas City.

The controversy in the lower Kansas has cast its shadow over two other major tributaries, the Osage, which is called the Marais des Cygnes, in Kansas, and the Grand in Missouri, and no construction progress has yet been made on water resource developments in these basins. In the Osage, however, a comprehensive plan has been formulated by the Corps of Engineers and has been authorized by Congress. Detailed planning is scheduled to be initiated this year on several projects, and it is probable that development in this basin will begin in the near future. Development of a comprehensive plan for the Grand River Basin is well advanced.

Tributary Reservoirs

In the western and northern part of the Missouri Basin, construction of a number of tributary reservoir projects has been initiated, largely by the Bureau of Reclamation. Most of these projects are primarily in the interest of irrigation, but many include flood control storage as well. In accordance with the 1944 Flood Control Act, the amount of flood control storage and the regulations for its operation are prescribed by the Corps of Engineers. Similarly, the Corps of Engineers operates irrigation storage in its multiple purpose reservoirs in accordance with the desires of the Bureau of Reclamation. Thus coordination of operation is assured.

The tributary reservoirs of the Bureau of Reclamation are scheduled to have a total power generating capacity of 1,200,000 kilowatts. These power plants and the 1-1/2 million kilowatts on the main stem will generate an average of about 15 billion kilowatt hours annually. Marketing of all of this power is handled by the Bureau of Reclamation under the provisions of the 1944 Flood Control Act.

Operation

1951 Flood

Although most of the interest in the basin program since 1946 has been in its construction phases, beginning in 1951 residents of the basin began to realize to an important degree some of the benefits which the basin development was to provide. In July of that year, intense storms over the Kansas River

Basin, which had been completely soaked by persistent rains extending back into May, produced the greatest flood of record on the Kansas River, with a peak flow of approximately 500,000 c.f.s. at its mouth at the Kansas Citys. The levees and flood walls in the Kansas City area were not entirely complete. The reservoir system upstream on the Kansas River, on which the levee designs were predicated, was not in existence except in some of the upper reaches, and the flood substantially exceeded the flood for which the works had been designed. Fig. 6 shows the areas affected. The Armourdale, Argentine, and Central Industrial District levees were overtopped. The levees on the Missouri were not overtopped, although the Fairfax unit was inundated by a break in a W.P.A. sewer which had not been built to withstand significant internal pressure. Ironically, a contract for the replacement of this sewer with a fully pressurized sewer had already been awarded at the time of the flood, but work had not yet been begun. Although the damages which resulted from this flood were catastrophic, $461,083,900 in Kansas City alone, the levees along the Missouri held and prevented $264,640,000 worth of damages. With the essential completion of the levee system, including replacement of the sewer, these savings would be increased to about $335,000,000.

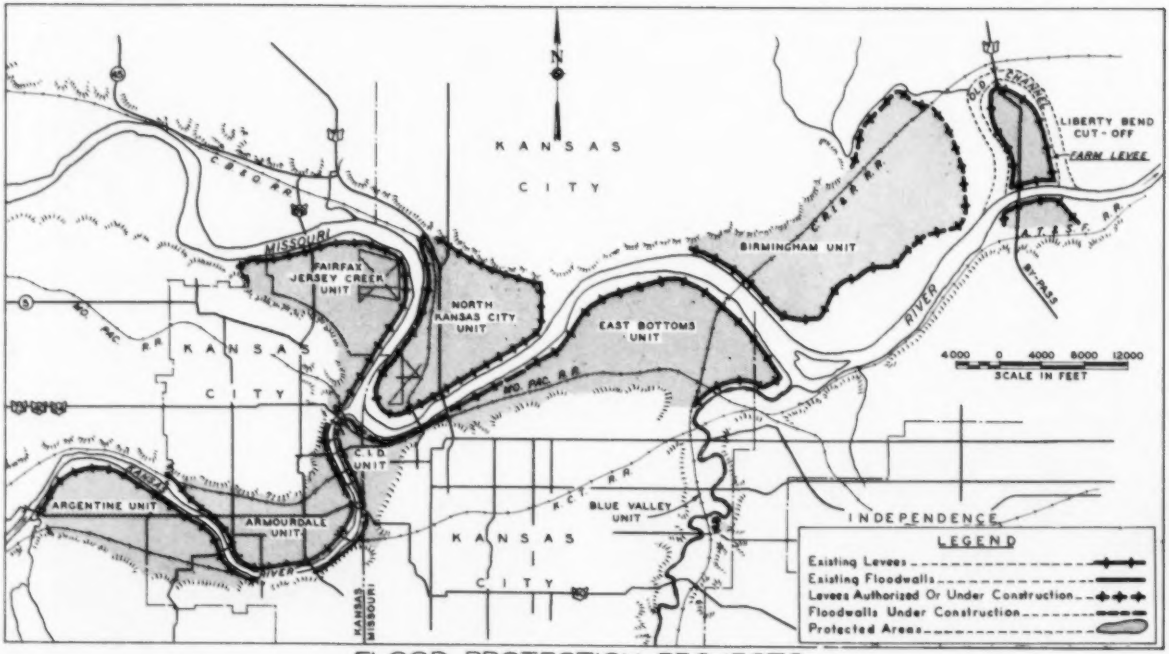
To protect the levee system along the Kansas River from a similar flood would require the completion of the authorized reservoirs in the Kansas River Basin, primarily Tuttle Creek, Milford, and Perry, together with several smaller reservoirs on the smaller tributaries close to Topeka and Kansas City. Despite all the damage which resulted from the flood, the important fact is that the works which had been installed actually prevented very substantial damages, and subsequent analyses have clearly demonstrated that complete protection against such a disaster is feasible.

1952 Flood

The Basin did not have to wait long for another striking demonstration of floods—and flood control. By March 1952 the accumulated snowfall over the plains area in eastern Montana and the Dakotas averaged 200 percent of normal. Generally it rested on a solid coating of ice over frozen ground. Then late in March a quick thaw started the floods on their way. The peak of the flood was accentuated by ice jams, a familiar phenomenon on the Missouri.

Communities along the Missouri like Bismarck, Pierre, and Sioux City, which normally are high and dry even in flood years, suffered substantial damage. As the flood passed below Sioux City, it spread out over the broad valley which reaches a maximum near Blair, Nebraska, of 17 miles. Scores of farming communities and hundreds of thousands of acres were inundated.

As the flood neared Omaha and Council Bluffs where Federal levees had been constructed, the communities geared themselves to an all out effort. Army engineers, contractors, Fifth Army troops, and thousands of volunteer citizens worked around the clock to raise the levees which had been designed for just such a flood or worse, but which depended on upstream reservoir storage not yet completed to take the peak off the flood. The levees had been designed for a flow of 250,000 c.f.s., but a flood peak of 400,000 c.f.s. was reached on 18 April. The levee squeaked by, with about a foot or two of free board. Fig. 7 shows the flood at about its peak. At this time only the Fort Peck Reservoir in Montana and a few small tributary reservoirs were available to store water, but they were able to reduce the peak stage a foot or two, or just about the amount of free board. This was a dramatic demonstration of what the comprehensive plan could do. Even more significant, however, is the fact that if that same flood were to occur today, the Garrison and Fort



FLOOD PROTECTION PROJECTS
KANSAS CITYS, MISSOURI & KANSAS

Fig. 6

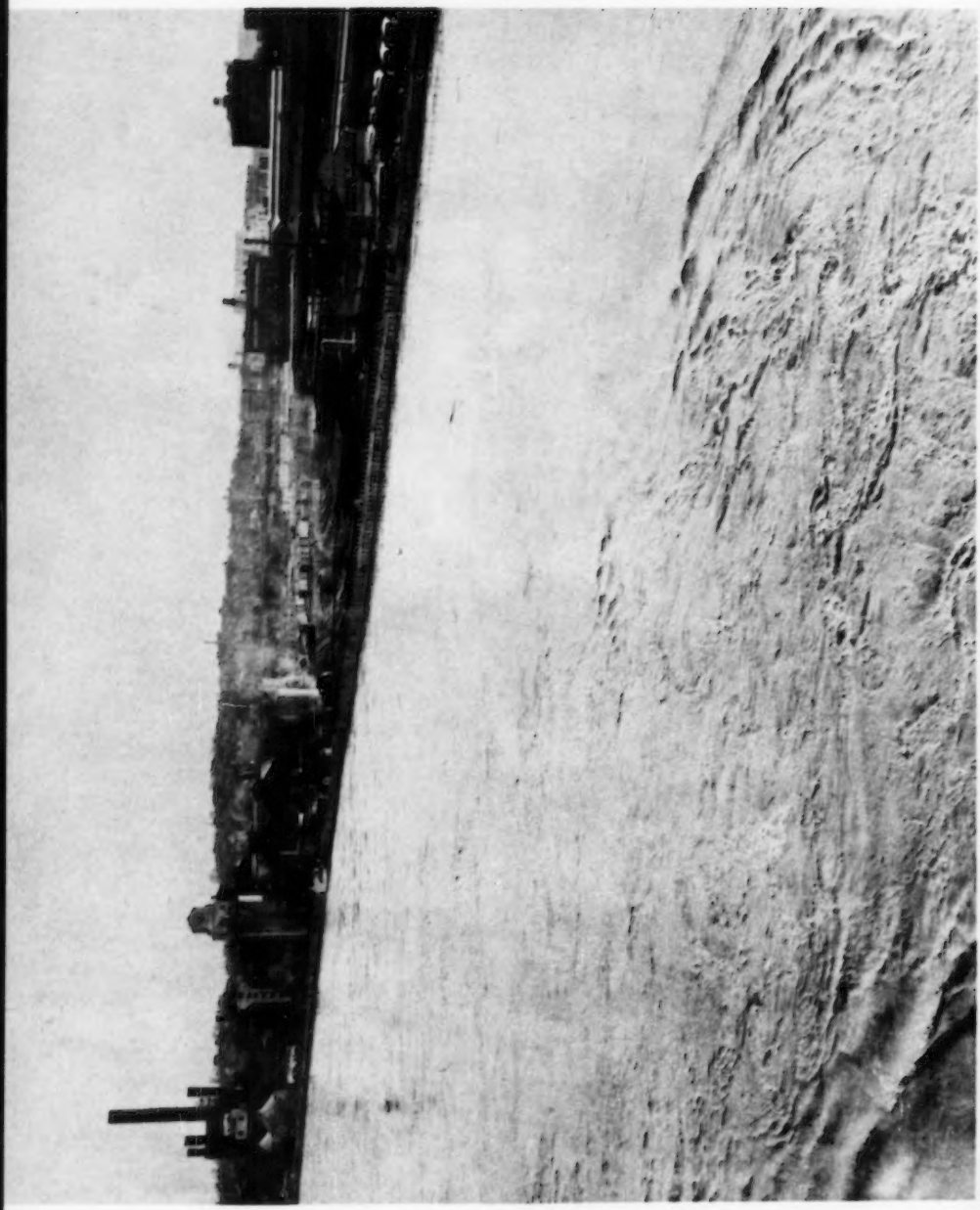


FIG. 7

CORPS OF ENGINEERS, U. S. ARMY
OMAHA DISTRICT
OMAHA, NEBRASKA

Photo No. 487
April 16, 1952

OMAHA FLOOD WALL

1952 Flood against Omaha Flood Wall at a height of about 1 foot below the crest stage. Downstream view taken from Douglas Street Bridge.

Randall Reservoirs would essentially store it all, and the flow at Omaha would be well below the banks. Fig. 8 shows the relation of the levee height to the actual flood stage and to stages as modified by various conditions of reservoir operation. Incidentally, surveys showed that the damages which were prevented at Omaha and Council Bluffs totalled over 60 million dollars or five times the cost of the levees.

Drouths

In 1953 the cycle of floods was partially reversed and drouths began to become the major problem, particularly in Kansas and Missouri. Here again the reservoir system began to pay dividends. In Kansas the completed reservoirs on the Smoky Hill and upper Republican assisted in maintaining an adequate flow on the Kansas River. In the upper Missouri, the Fort Peck Reservoir captured about two million acre feet of water from an early flood in Montana and used this water to maintain adequate flows for water supply, public health, and navigation downstream. The Fort Randall Reservoir, closed in July 1952, assisted materially in ironing out the fluctuations of the river and produced a more uniform flow than the Missouri had ever witnessed before. During the months of September and October, the stored water in the Missouri reservoirs was providing 75 percent of the total flow at Kansas City and about one-third of the flow at St. Louis. If it were not for Fort Peck Reservoir, navigation on the Mississippi to and above St. Louis would have been suspended in late September of that year. Fig. 9 shows the flows as they actually occurred and as they would have been without reservoir regulation.

Power Production

In March 1954 power production at Fort Randall began with one 40,000 KW generator, and since that time, at approximately three or four-month intervals, additional 40,000 KW units have been added. This power is being distributed to customers in South Dakota and Nebraska by the Bureau of Reclamation. Later this year more power will become available when initial generation begins at the Garrison project. By the end of this year main stem power capacity should approximate 565,000 KW. Revenues in F.Y. 1954 amounted to about $2,300,000 and will be very much higher in 1955. Figs. 10 and 11 show more data on power generation and power revenues.

Navigation

In 1954 benefits began to be realized in a substantial measure from another function of the water development program. Navigation on the Missouri River has for years been conducted on a pioneering basis, pending final stabilization of the waterway and the development of a nine-foot channel. In 1954, however, two private towing companies conducted regular operations on the river and initiated plans for expanding their activities on a large scale. This year the Federal Barge Lines have placed a new 3600 HP, 4-screw, 10-rudder towboat in service, and the Sioux City & New Orleans Barge Lines have placed a new 3200 HP towboat in service. Other carriers are taking an increased interest in Missouri River traffic.

Municipalities and private concerns are constructing dock facilities for handling of cargo all along the river. New facilities have been provided at Chamois, Randolph and St. Joseph, Missouri, and at Nebraska City and Brownville, Nebraska. Existing facilities at Omaha, the Kansas Citys and other localities are being expanded and improved. One of the interesting collateral

1952 FLOOD STAGES AT OMAHA AND COUNCIL BLUFFS

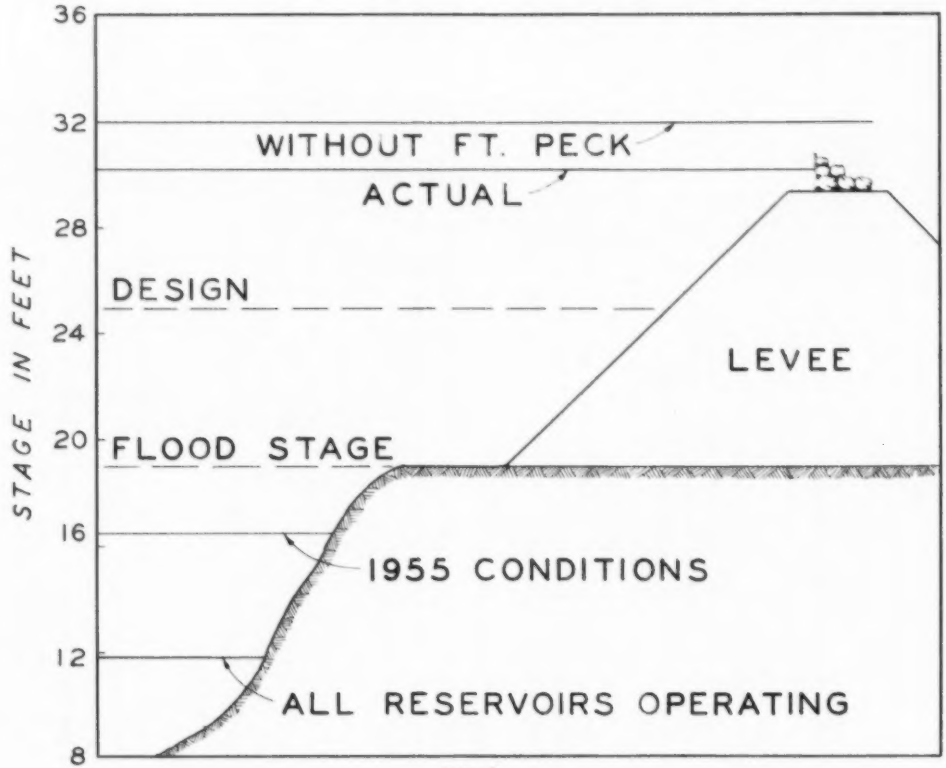


FIG. 8

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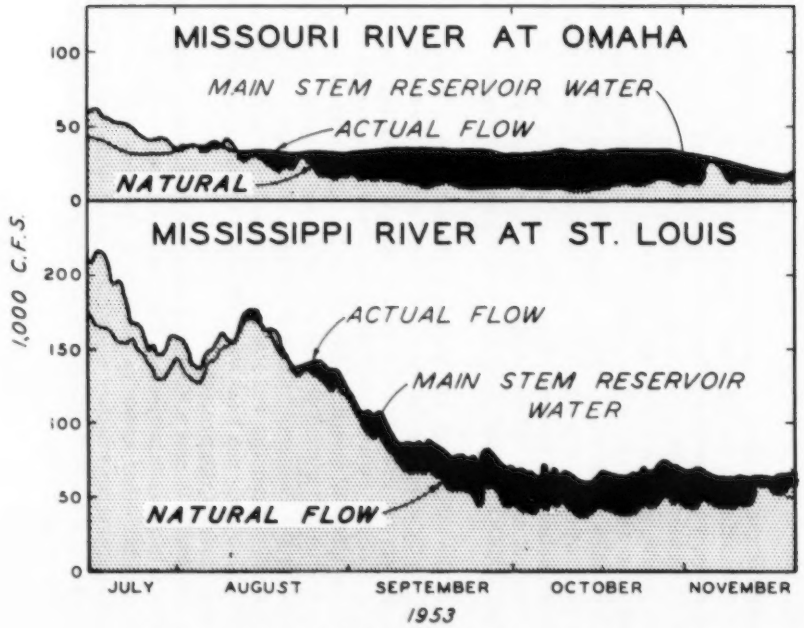


Fig. 9 FLOW AUGMENTATION DURING DROUGHT

benefits of navigation is the growing demand for river front industrial sites accessible both to an assured water supply and a good navigable waterway. Commercial traffic, which reached a low of 52,000 tons in 1952, increased to 150,000 tons in 1953 and 287,000 tons in 1954. This year operators are predicting 500,000 to 600,000 tons. Most of the traffic upstream is coal, steel, fuel, and molasses. Downstream cargo is largely grain. A traffic study made in 1950 indicated that traffic should reach 5 million tons in 20 years after the project was completed. It now appears that this forecast was too conservative both as to amount of traffic and the time it would take to develop. Fig. 12 shows tonnage experienced during the last few years and that estimated for 1955.

Basin Coordination

Coordination of the planning, construction and operation phases of the development is handled by the Missouri Basin Inter-Agency Committee which is composed of one representative from the Departments of Army; Interior; Agriculture; Commerce; Health, Education and Welfare; Labor; the Federal Power Commission, and the Governors of each of the Basin States. The Committee meets once every one or two months, rotating its meeting places so that it meets in each of the Basin states about once each year. Working subcommittees meet oftener, some on almost a continuous basis. This type of voluntary coordination has worked amazingly well and has served not only to smooth out Federal agency relationships, but also to insure that the interests of the affected states and local citizens are adequately recognized and provided for.

Operation of the main stem reservoirs are handled by a Reservoir Control Center located in Omaha. On the basis of water supply forecasts and estimated demands, this group prepares a tentative annual operating plan which is submitted to a group of representatives of the Federal agencies and the State Engineers of the affected states. After all of the comments of the group are received and discussed, a final plan is prepared and adopted. Execution of the plan is handled by the Reservoir Control Center, but close liaison is maintained with the other agencies and states. This arrangement, although it may be somewhat unorthodox, has been very effective in insuring proper balance between all functions of the project.

The program which is now authorized constitutes a basic framework of the larger and more important projects. The Corps of Engineers, the Bureau of Reclamation, and the other agencies and states are constantly re-examining the program to determine whether modifications or additions are required. Additional projects are recommended to Congress as studies indicate their need and economic justification.

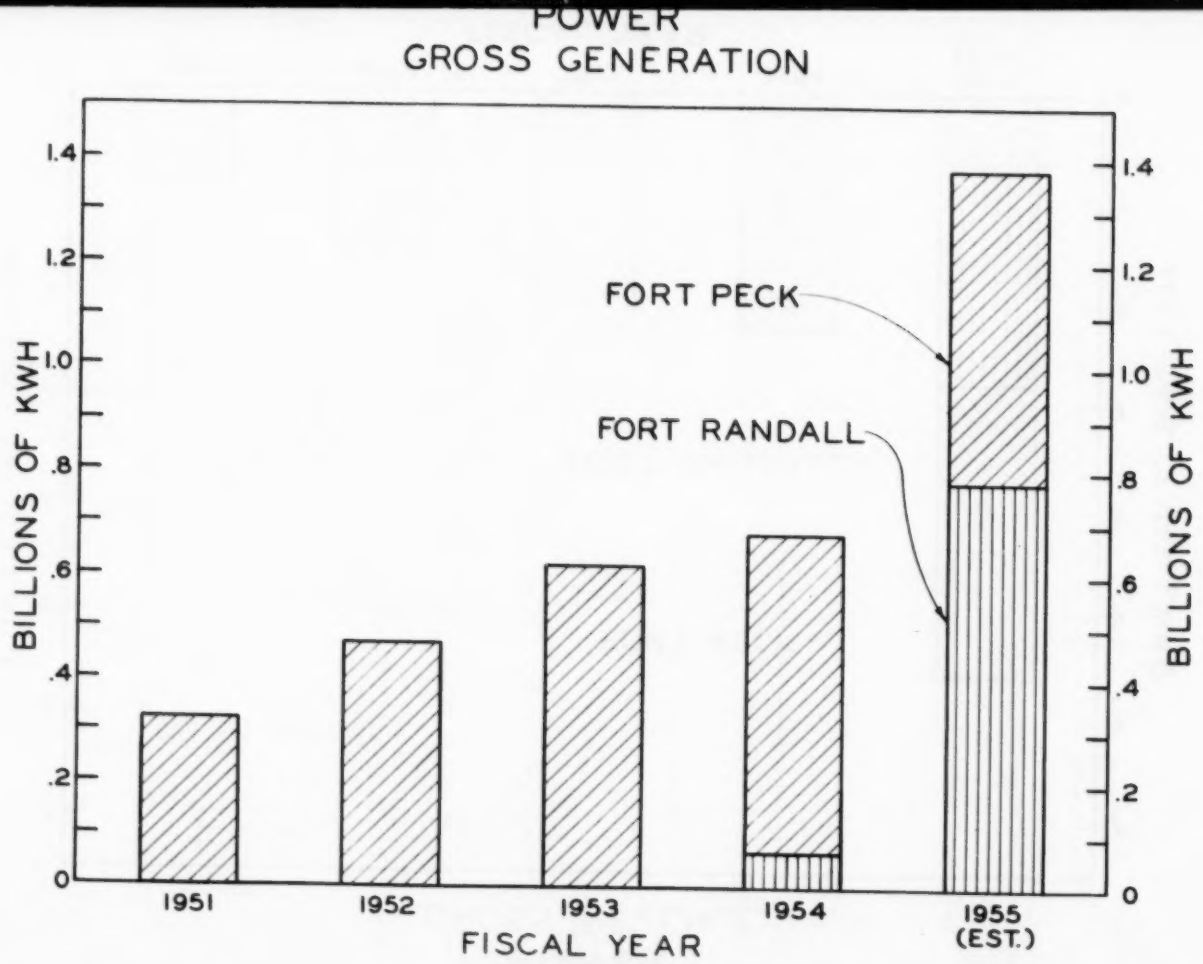
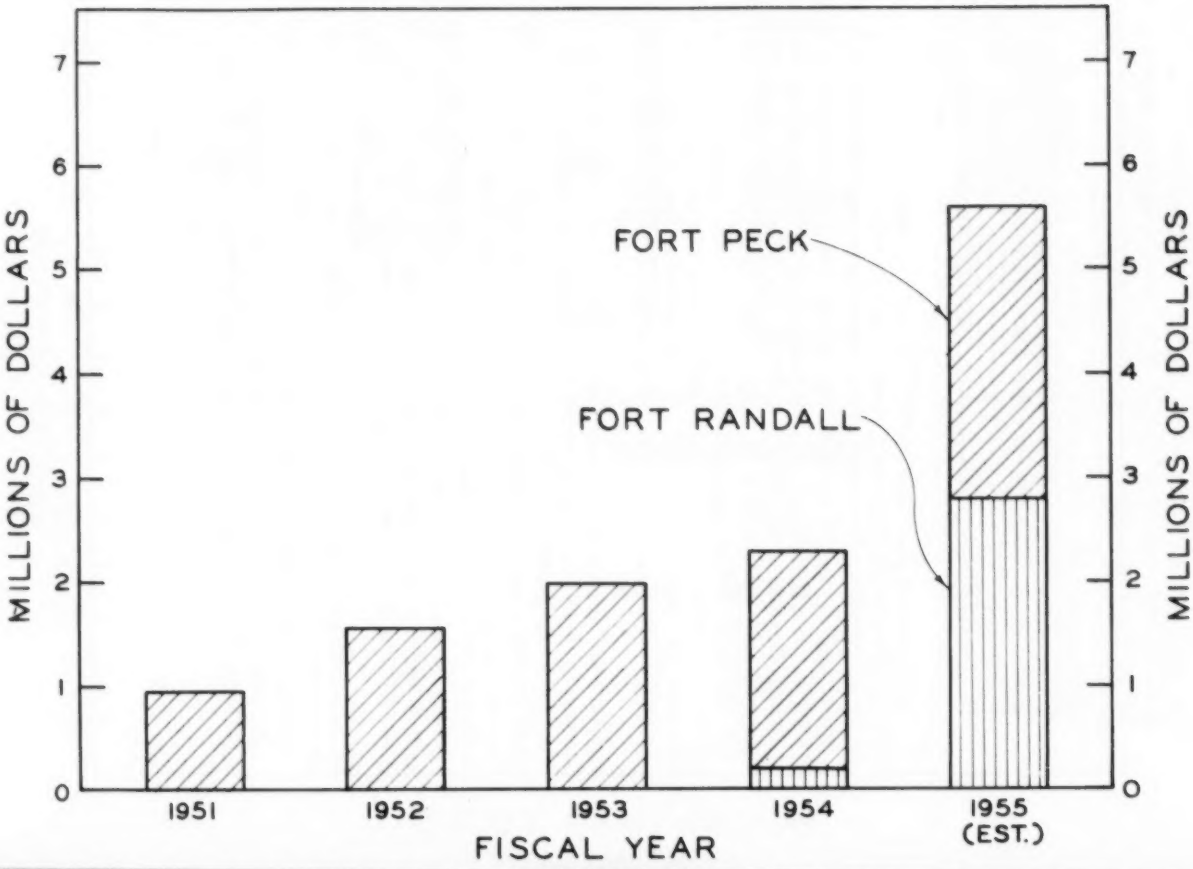

POWER
GROSS GENERATION
BILLIONS OF KWH
1.4
1.2
1.0
.8
.6
.4
.2
0
FORT PECK
FORT RANDALL
1951
1952
1953
1954
1955
(EST.)
FISCAL YEAR

Fig. 10

POWER
GROSS REVENUE



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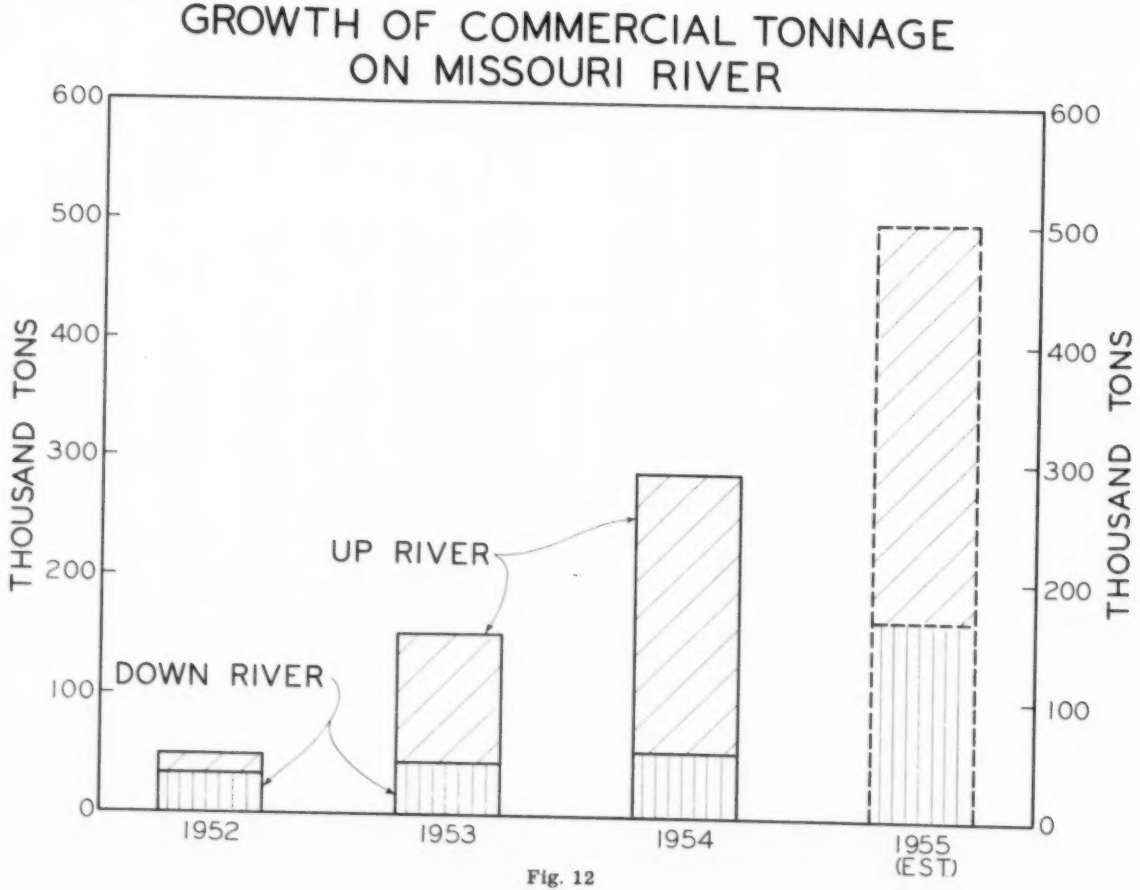
GROWTH OF COMMERCIAL TONNAGE
ON MISSOURI RIVER
THOUSAND TONS
600
500
400
300
200
100
0
UP RIVER
DOWN RIVER
1952
1953
1954
1955
(EST)

Fig. 12

PROCEEDINGS PAPERS

The technical papers published in the past year are presented below. Technical-division sponsorship is indicated by an abbreviation at the end of each Paper Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU), and Waterways (WW) divisions. For titles and order coupons, refer to the appropriate issue of "Civil Engineering" or write for a cumulative price list.

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SEPTEMBER: 484(ST), 485(ST), 486(ST), 487(CP)[c], 488(ST)[c], 489(HY), 490(HY), 491(HY)[c], 492(SA), 493(SA), 494(SA), 495(SA), 496(SA), 497(SA), 498(SA), 499(HW), 500(HW), 501(HW)[c], 502(WW), 503(WW), 504(WW)[c], 505(CO), 506(CO)[c], 507(CP), 508(CP), 509(CP), 510(CP), 511(CP).

OCTOBER: 512(SM), 513(SM), 514(SM), 515(SM), 516(SM), 517(PO), 518(SM)[c], 519(IR), 520(IR), 521(IR), 522(IR)[c], 523(AT)[c], 524(SU), 525(SU)[c], 526(EM), 527(EM), 528(EM), 529(EM), 530(EM)[c], 531(EM), 532(EM)[c], 533(PO).

NOVEMBER: 534(HY), 535(HY), 536(HY), 537(HY), 538(HY)[c], 539(ST), 540(ST), 541(ST), 542(ST), 543(ST), 544(ST), 545(SA), 546(SA), 547(SA), 548(SM), 549(SM), 550(SM), 551(SM), 552(SA), 553(SM)[c], 554(SA), 555(SA), 556(SA), 557(SA).

DECEMBER: 558(ST), 559(ST), 560(ST), 561(ST), 562(ST), 563(ST)[c], 564(HY), 565(HY), 566(HY), 567(HY), 568(HY)[c], 569(SM), 570(SM), 571(SM), 572(SM)[c], 573(SM)[c], 574(SU), 575(SU), 576(SU), 577(SU), 578(HY), 579(ST), 580(SU), 581(SU), 582(Index).

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JANUARY: 583(ST), 584(ST), 585(ST), 586(ST), 587(ST), 588(ST), 589(ST)[c], 590(SA), 591(SA), 592(SA), 593(SA), 594(SA), 595(SA)[c], 596(HW), 597(HW), 598(HW)[c], 599(CP), 600(CP), 601(CP), 602(CP), 603(CP), 604(EM), 605(EM), 606(EM)[c], 607(EM).

FEBRUARY: 608(WW), 609(WW), 610(WW), 611(WW), 612(WW), 613(WW), 614(WW), 615(WW), 616(WW), 617(IR), 618(IR), 619(IR), 620(IR), 621(IR)[c], 622(IR), 623(IR), 624(HY)[c], 625(HY), 626(HY), 627(HY), 628(HY), 629(HY), 630(HY), 631(HY), 632(CO), 633(CO).

MARCH: 634(PO), 635(PO), 636(PO), 637(PO), 638(PO), 639(PO), 640(PO), 641(PO)[c], 642(SA), 643(SA), 644(SA), 645(SA), 646(SA), 647(SA)[c], 648(ST), 649(ST), 650(ST), 651(ST), 652(ST), 653(ST), 654(ST)[c], 655(SA), 656(SM)[c], 657(SM)[c], 658(SM)[c].

APRIL: 659(ST), 660(ST), 661(ST)[c], 662(ST), 663(ST), 664(ST)[c], 665(HY)[c], 666(HY), 667(HY), 668(HY), 669(HY), 670(EM), 671(EM), 672(EM), 673(EM), 674(EM), 675(EM), 676(EM), 677(EM), 678(HY).

MAY: 679(ST), 680(ST), 681(ST), 682(ST)[c], 683(ST), 684(ST), 685(SA), 686(SA), 687(SA), 688(SA), 689(SA)[c], 690(EM), 691(EM), 692(EM), 693(EM), 694(EM), 695(EM), 696(PO), 697(PO), 698(SA), 699(PO)[c], 700(PO), 701(ST)[c].

JUNE: 702(HW), 703(HW), 704(HW)[c], 705(IR), 706(IR), 707(IR), 708(IR), 709(HY)[c], 710(CP), 711(CP), 712(CP), 713(CP)[c], 714(HY), 715(HY), 716(HY), 717(HY), 718(SM)[c], 719(HY)[c], 720(AT), 721(AT), 722(SU), 723(WW), 724(WW), 725(WW), 726(WW)[c], 727(WW), 728(IR), 729(IR), 730(SU)[c], 731(SU).

JULY: 732(ST), 733(ST), 734(ST), 735(ST), 736(ST), 737(PO), 738(PO), 739(PO), 740(PO), 741(PO), 742(PO), 743(HY), 744(HY), 745(HY), 746(HY), 747(HY), 748(HY)[c], 749(SA), 750(SA), 751(SA), 752(SA)[c], 753(SM), 754(SM), 755(SM), 756(SM), 757(SM), 758(CO)[c], 759(SM)[c], 760(WW)[c].

AUGUST: 761(BD), 762(ST), 763(ST), 764(ST), 765(ST)[c], 766(CP), 767(CP), 768(CP), 769(CP), 770(CP), 771(EM), 772(EM), 773(SA), 774(EM), 775(EM), 776(EM)[c], 777(AT), 778(AT), 779(SA), 780(SA), 781(SA), 782(SA)[c], 783(HW), 784(HW), 785(CP), 786(ST).

SEPTEMBER: 787(PO), 788(IR), 789(HY), 790(HY), 791(HY), 792(HY), 793(HY), 794(HY)[c], 795(EM), 796(EM), 797(EM), 798(EM), 799(EM)[c], 800(WW), 801(WW), 802(WW), 803(WW), 804(WW), 805(WW), 806(HY), 807(PO)[c], 808(IR)[c].

c. Discussion of several papers, grouped by Divisions.

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